THE CONSERVATION AND PRESERVATION OF SOIL FERTILITY

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Within a hundred miles of the spot where the first permanent English settlement was made in our country one can to-day buy hundreds of thousands of acres of arable land for less than $10 an acre—land that was once valued at $50 an acre, and would now be worth more than $100 an acre if its fertility had been maintained. This statement does not include any reference to lands that have seriously suffered from soil erosion, but only to great areas of nearly level or gently undulating farm lands whose productive power has been almost destroyed by a hundred years or more of common cultivation by American farmers.

The two and one-half billion bushel corn crop of the United States is mostly produced on land not subject to injury by surface washing, and in the main this is also true of the half-billion bushels of wheat from the principal wheat-producing states.

The greatest material problem of the United States is not in the development of the waterways, not in the preservation of forests, and not in the conservation of our coal and iron, important as these all are; but the problem that is vastly greater than all of these is to bring about the adoption of systems of farming that will maintain or increase the productive power of American soils.

We must not deceive ourselves with general statistics which show some increase in average crop yields in some states. Thus, in the new state of Illinois the average yield of corn has increased in the past ten years, but this does not prove that Illinois soils are growing richer. During the past ten years the annual corn area of Illinois has increased from 7 million acres to 9 million acres, and the added 2 million acres are the richest black soil of the state, reclaimed by dredge ditching and tile drainage; while the 7 million acres are producing smaller crops than ten years ago.

It is sometimes asked how it is that the soils of Rhode Island and Connecticut produce more corn per acre than those of Illinois.

Because Rhode Island and Connecticut make large use of plant food materials, including much manure produced in part from Illinois corn, oats and bran. It is well to know, however, and well to remember, lest we be deceived by false arguments, that the corn acreage of Rhode Island is less than half of one township; that the corn acreage of Rhode Island and Connecticut combined is less than one-tenth of one Illinois county; and that the total corn acreage of Rhode Island, Connecticut, Massachusetts, Maine, New Hampshire, Vermont, New York, New Jersey, Pennsylvania, Delaware and Maryland all combined is less than the corn acreage of Georgia. The acreage of corn in Illinois is twice as large and the average yield three times as large as that of Georgia.

It is sometimes asked how it is that the old lands of Germany, for example, produce more wheat per acre than the United States. Lest we be deceived, we should know that Germany produces 125 million bushels of wheat, and, in addition, Germany imports 75 million bushels of wheat, 40 million bushels of corn, more than a billion pounds of oil cake, and other foodstuffs from which much manure is made; and, besides all this, Germany uses large quantities of phosphates and other commercial plant food materials.

And what does Germany export? Her principal export is two billion pounds of sugar, which contains no plant food of value.

Similar statements may be made of England, France, Belgium, Holland and of all small countries, or small states, or small districts near large cities where the productive capacity of the soil is maintained. Thus Denmark produces 4 million bushels of wheat, and in addition Denmark imports 5 million bushels of wheat, 15 million bushels of corn, 800 million pounds of oil cake and other foodstuffs, phosphates, etc., and Denmark exports 175 million pounds of butter, which contains no plant food of value, but which sells for more than these imports cost.

If anyone knows anything of American agriculture he knows that, as a general rule, old land is poorer than new land; that the practice of the present art of agriculture tends toward land ruin. Therein lies the fact that points toward future poverty for our children. If old lands were richer than new lands, then would the soils of old Virginia be more valuable than those of Illinois. The United States is one of the greatest agricultural countries, and without agriculture America is nothing.

There are but three other great agricultural countries comparable with the United States. Consider for a moment their history and present condition: China, India, Russia—names almost synonymous with famine, where millions of people die of starvation every few years.

Not only on the black cotton soils of India, where five acres of land are now required to produce one bale of cotton; not only on the black earth soils of Russia, where eight bushels is the average yield of wheat, with fallow every third year, but also on the black corn soils of America, the practice of the art of agriculture tends toward land ruin.

If the art of agriculture has reduced the productive power of American soil, then the science of agriculture must restore it, and the key to the problem for our most common agricultural land is the element phosphorus. Phosphorus is the only element of value contained in the mineral called phosphate.

There are three elements of plant food that have recognized market values—nitrogen, phosphorus and potassium, and the inventory of our natural resources must include the supply of each of these three elements.

Are our common farm lands rich in nitrogen? No. Do we have anywhere an inexhaustible supply of nitrogen? Yes. There is contained in the air over every acre sufficient nitrogen for a hundred bushels of corn every year for 700,000 years; and this supply can be drawn upon any time and always, both by us and by our children. Indeed, the nitrogen can be gotten from the air not only without expense, but with profit in the getting, because such crops as clover and alfalfa, which by means of symbiotic bacteria have power to utilize atmospheric nitrogen, are valuable crops to raise for their own sake, and where these are plowed under liberally, either directly or in manure, nitrogen is thus supplied for the production of any other crop.

What do we know regarding the element potassium? We know that if the composition of our common plowed soil were the same as the average composition of the solid crust of the earth, based upon the analysis of 2110 samples of common rocks by the United States Geological Survey, then the plowed soil of one acre would contain sufficient potassium for a hundred bushels of corn every year for 2590 years, assuming that the corn stalks are returned to the land,

either directly or in farm manure. In other words, potassium is one of the abundant elements in the earth's crust and, consequently, in all normal soils. Thus several hundred analyses by the Illinois Experiment Station have shown that the average corn belt land contains sufficient potassium in the plowed soil for a hundred bushels of corn per acre every year for as long as the time since Christ walked among men—or sufficient potassium for the average corn yield of the United States every year for as long as since Adam began to till the soil. In addition to this are the great potash mines of North Germany, covering a million acres and now estimated to contain sufficient potassium to meet the present rate of production for 190,000 years; and when these are gone the people of earth can recover potassium from the absolutely inexhaustible supply of the boundless ocean, as is already being done to some extent in Southern France.

One hundred bushels of corn contains 19 pounds of potassium and 17 pounds of phosphorus; and, while the average crust of the earth contains two and one-half per cent. (2½%) of potassium, it contains only one-tenth of one per cent. (0.1%) of the element phosphorus; and the most common agricultural lands of the United States contain in the plowed soil no more total phosphorus than would be required for a crop of a hundred bushels of corn per acre during the full life of one man. If such crops had been removed from our common corn belt lands every year since Columbus discovered America they would have required every pound of phosphorus contained in that soil to a depth of four feet.

For the adoption of systems of permanent agriculture under which our common lands shall grow better instead of poorer, the nitrogen problem is to secure it from the absolutely inexhaustible supply in the air, and the potassium problem is to liberate it as rapidly as necessary from the practically inexhaustible supply in the soil, while the phosphorus problem is to get all we can and keep all we get. But what are we doing? We are exporting every year for less than 6 million dollars sufficient phosphorus for the production of 600 million dollars' worth of corn, while the element phosphorus already limits the yield of corn on the commonest corn belt land.

Few scientific facts are better established than these. A single illustration will show the possibility of increasing the productive

power of the land with proper treatment and the certainty of soil depletion even under a good crop rotation without the addition of plant food.

For sixty years at Rothamsted, England, the oldest agricultural experiment station in the world, a four-year rotation of turnips, barley, clover (or beans) and wheat has been grown on Agdell Field, where the soil is of normal composition. There are three sections in this field; no plant food has been applied to one, minerals including phosphorus to the second, and the same with nitrogen added to the third. As an average of the last twenty years, corresponding to the average yield just fifty years from the beginning of the experiments, the following results per acre were obtained:

Soil Treatment.	None.	Minerals.	Minerals and Nitrogen.
Turnips, tons	.5	12.6	20.9
Barley, bushels	13.7	22.2	29.2
Clover, tons	.4	1.9	1.7
Beans,* bushels	16.0	28.3	19.6
Wheat, bushels	24.3	38.4	36.4

*Beans were grown where clover failed.

Rapid Land Ruin in the United States

Among all the nations of the earth the United States stands first in rapidity of soil exhaustion. The improvement of seed, the use of tile-drainage, the invention and immediate adoption of labor-saving agricultural machinery, the wonderful development of cheap and rapid means of transportation, and the opening of the world's markets to the American farmer have all combined to make possible and to encourage the rapid depletion of American soils, until agricultural ruin already exists, practically, over vast areas in the older parts of this new country, the United States of America, while it is common knowledge that even in the new rich corn belt most lands that have been under cultivation for half a century are less productive now than they once were.

The almost universal practice of the civilized world to this date has been to ruin land and then to seek out newer lands on which to repeat the process even more quickly. There is extreme poverty among the people of the world almost wherever they are dependent for support upon the agricultural resources of ordinary land that has been under cultivation for two centuries.

If we are ever to adopt systems of soil improvement it must be done while we are prosperous. People living in poverty on impoverished lands have no money to invest in the improvement of their farms, no matter how great returns such investments would promise in future years. Soils that have been running down for a century cannot be built up economically in a year so as to pay an immediate profit on the improvements.

Plant Food in Rich Soils

Lands that are valuable produce large crops. Soils that produce large crops are rich soils. Rich soils contain a large store of plant food. If we are to maintain our lands in a high state of productiveness and at a high value we must maintain in our soils a large supply of every essential element of plant food.

It is worth while to remember that there are ten essential elements of plant food. If the supply of any one of these elements fails the crop will fail. These ten elements are carbon and oxygen, taken into the leaves of the plant from the air as carbon dioxide; hydrogen, a constituent of water, absorbed through the plant roots; nitrogen, taken from the soil by all plants and also secured from the air by legumes; phosphorus, potassium, magnesium, calcium, iron and sulphur, all of which are secured only from the soil.

The soil nitrogen is contained in the organic matter, or humus, and to maintain the supply of nitrogen we should keep the soil well stored with organic matter, making liberal use of clover or other legumes which have power to secure nitrogen from the inexhaustible supply in the air, the clover being plowed under either directly or as farm manure.

It is interesting to know that an acre of soil seven inches deep, if it possessed the average composition of the earth's crust, would contain sufficient iron to meet the needs of one hundred bushels of corn every year for 200,000 years, sufficient calcium for 55,000 years, magnesium for 7,000 years, sulphur for 10,000 years, and potassium for 2,600 years, but sufficient phosphorus for only 130 years.

These numbers are based upon the average composition of the earth's crust in accordance with the most recent computations of Professor F. W. Clarke, of the United States Geological Survey. They are certainly significant to the student of soil fertility, although

perhaps no soil possesses exactly the average composition of the entire crust of the earth.

As stated above, the nitrogen resting on an acre of the earth's surface is sufficient for 100 bushels of corn every year for 700,000 years, although the nitrogen contained in the plowed soil of an acre is rarely sufficient for more than fifty such crops.

Only two essential elements of plant food are becoming deficient in the ordinary soils of the United States. These are nitrogen and phosphorus, neither of which is contained in the plowed soil of our commonest lands in larger quantity than would be required for maximum crops during the full time of one life.

There are some soils whose fertility can be maintained at low-yielding power by crop rotation alone. This is on sloping land whose surface soil is washed away at least as rapidly as the fertility is removed by crops and whose subsoil is as rich or richer than the surface in mineral plant food. Some soils of this topography, with subsoils rich in mineral plant food, have been cropped for centuries with the production of two or three grain crops every ten or twelve years, the intervening years providing for the accumulation of nitrogen by legumes while the land is kept in pasture. These lands are valued at about $10 to $20 an acre, and this value can be maintained indefinitely without the application of farm manures or other plant food materials. But it is impossible to maintain our common prairie and level upland timber soils at their present value and productive power if we continue to remove from these lands larger amounts of phosphorus and nitrogen than are returned.

It is certainly good farm practice, and usually the best farm practice, to remove the largest possible quantities of plant food from the soil, for the simple reason that large crops require large quantities of plant food; but it is no less important to restore to the soil, when needed, even larger quantities of plant food than are removed—by turning under legume catch crops and crop residues not removed from the field, by returning manures produced on the farm, and so far as necessary by the purchase of commercial plant food, such as phosphorus in bone meal or rock phosphate, or if needed, potassium in concentrated potassium salts.

Effect of Crop Rotation

It will be well to consider in some detail the effect of crop rotation on soil fertility. Suppose we are practicing a four-year rotation, including corn for two years, oats with clover seeding the third year, and clover for hay and seed crops the fourth year. Let us assume such crop yields as have been produced and as can be produced, in normal seasons on the richest, best treated land, with good seed and good farming, namely, 100 bushels of corn per acre, 100 bushels of oats and 4 tons per acre of clover, including, perhaps, 3 tons in the hay crop and 1 ton in the seed crop. If we do not succeed in securing these yields we should at least try to make such yields possible, and we should approach as near to them as we can. On the best treated land at the University of Illinois 88 bushels of corn per acre have been produced as an average of the last six years, and on three different soil experiment fields in the state we have harvested more than 90 bushels of oats per acre.

Let us first consider the phosphorus required for this rotation. The two crops of corn will each require 23 pounds, 17 for the grain and 6 for the stalks; the oat crop will require 16 pounds of phosphorus, about 11 for the grain and 5 for the straw, and the 4-ton crop of clover will require 20 pounds of phosphorus. Thus we see that 87 pounds of the element phosphorus will be required for the rotation. If we leave the stalks on the land the requirement is reduced to 70 pounds of phosphorus, or to about 17 pounds a year per acre.

Suppose the soil contains in the first 7 inches 1200 pounds of phosphorus per acre, which is about the average of the principal type of soil in the corn belt; how many years would be required to remove this amount from the land if it could be drawn upon at this rate? Only seventy years. On the other hand, suppose with this crop rotation we can secure from the soil the equivalent of only one per cent. of the phosphorus contained in the first 7 inches. This would be only 12 pounds of phosphorus a year, which would necessarily reduce the crop yields much below the amounts suggested above, and with the further reduction in the total amount of phosphorus year by year, the crop yields must be reduced accordingly.

On the ordinary soils of the United States ultimate failure is the only future for this system of farming, even if we consider the

phosphorus alone; although the phosphorus may be returned in bone meal, in acid phosphate, in raw rock phosphate, or in sufficient amounts of farm manure.

If we consider the element nitrogen in this system of farming we find that 200 bushels of corn require about 200 pounds of nitrogen, aside from that required for the stalks, and the stalks must be returned to the land without burning, otherwise the 96 pounds of nitrogen required for the two crops of stalks, will also be removed from the land. The oats crop will remove 97 pounds of nitrogen, making 297 pounds per acre for the corn and the oats.

The four tons of clover will contain about 160 pounds of nitrogen and the clover roots and stubble about one-half as much as the tops, or 80 pounds per acre. If all of the nitrogen contained in the entire clover crop is taken from the air the rotation would add only 80 pounds of nitrogen to the soil, while the corn and oats would remove 297 pounds.

How, then, is it possible to maintain the supply of nitrogen by this rotation? It is not possible. Under such a rotation, with all crops removed except the corn stalks, the supply of nitrogen grows less and less. Where this rotation is successful for a time it is due to the fact that the soil nitrogen has been drawn upon year by year, while the chief effect of the clover has been to extract phosphorus from the soil for its own growth and for the use of succeeding crops.

There is another point to be considered in reference to nitrogen. On land that is capable of furnishing sufficient nitrogen for even a 50-bushel crop of corn the clover crop will undoubtedly draw a third of its nitrogen from the soil and not more than two-thirds from the air. Consequently, since two-thirds of the nitrogen in the entire plant is removed in the tops, the roots and stubble will leave no more nitrogen in the soil than the plant takes from the soil. How, then, can we maintain the supply of nitrogen in the soil? By plowing under sufficient clover or by applying sufficient farm manure or, better, by using both of these means.

If all the crops grown in the rotation are fed, including the corn stalks, containing a total of 533 pounds of nitrogen from four acres, and if three-fourths of this, or 400 pounds, are returned in the manure, we have sufficient to replace the 393 pounds removed in the corn and oat crops, and we may assume that the 160 pounds of nitrogen removed in the clover came from the air. Of course, some

additional nitrogen will be saved in the straw and stalks which are used directly for bedding and not for feed.

How shall the grain farmer maintain the nitrogen in his soil? Possibly this can be done by plowing under everything produced except the grains and the clover seed, preferably only one corn crop being grown in the rotation.

The problem of maintaining the nitrogen in live stock farming becomes easier if we extend the rotation to include about two years of pasture, using a mixture, perhaps, of red clover, alsike, timothy and red top instead of seeding red clover only with the oats. In this case three grain crops, as corn, oats and wheat, or corn two years and oats one year, could be grown during the six-year rotation, the land being kept in meadow and pasture one-half of the time.

Use and Value of Farm Manure

Farm manure always has been, and without doubt always will be, the principal material used in maintaining the fertility of the soil; but it is an unquestionable fact that the greatest source of loss to American agriculture to-day is in the enormous waste of farm manure. If corn were worth $1.05 a bushel, then the average annual value of the corn crop of the United States would be equal to the average value of the total farm manure annually produced in this country.

The positive or intrinsic value of farm manure lies in the amounts of valuable plant food which it contains. It also possesses an important indirect value as a soil stimulant, due to its power as it ferments and decays in contact with the soil, to liberate from the soil plant food that would not otherwise become available so quickly. There is still another distinct value in farm manure, due to the fact that it makes the soil more porous and spongy and thus increases the power of the soil to absorb and retain moisture and to resist surface washing. This third value of farm manure is due to improvement in physical condition.

The value of farm manure for its physical improvement of the soil is commonly fully appreciated, and frequently overestimated by popular agricultural writers, while its value for the plant food which it supplies and for that which it liberates from the soil is sometimes almost ignored. There is no good excuse for erroneous teaching regarding these different values, because there exists a vast amount

of positive information both from practical experience and from exact scientific investigations.

Thus, organic matter from peat beds hauled out and spread on the land and incorporated with the soil produces no such effects on crop yields as are produced by good farm manure. Why? Because the peat does not decay readily, so as to furnish plant food either by its own decomposition or by liberating it from the soil; and yet the peat has as great power as farm manure for physical improvement of the soil.

Manure made from clover hay and heavy grain rations has much greater value than manure made from wheat straw. Why? Is it because they affect the physical conditions of the soil in different ways? No. The great difference in value is due to the difference in plant food and in rapidity of decay.

At the Rothamsted Agricultural Experiment Station, England, on a field to which no manure and no plant food have been applied the average yield of wheat has been 12.9 bushels per acre for more than half a century. Land treated with a heavy annual application of farm manure has produced 35.5 bushels of wheat per acre as an average during 55 years. Another field treated with commercial plant food without organic matter has produced 37.1 bushels of wheat per acre as an average during the same time. The latter field received a little less plant food than was furnished in the manure, thus furnishing ample proof of the value of plant food supplied and showing that the physical effect of the farm manure was by no means so important.

Nevertheless, the physical effect should not be overlooked. Under certain seasonal conditions this physical value may be very important. Thus, in the very dry season of 1893 at Rothamsted the land fertilized with commercial plant food produced only 21.7 bushels of wheat per acre, while the farm manure plot produced 34.2 bushels the same year.

In semi-arid regions the physical condition of the soil and its power to absorb and retain moisture may be the controlling factor in crop yields, but where the average annual rainfall is 28 inches as at Rothamsted or 37 inches as in Illinois, with a fairly uniform distribution during the growing season, the physical conditions of the soil in relation to crop yields may be compared to the shelter and other physical surroundings provided for live stock. In other words,

under normal conditions the controlling factor is food, for crops as well as for live stock.

While manure has some value for physical improvement and a larger value in its power to liberate plant food from the soil, it should be clearly understood and always borne in mind that the great value of farm manure, especially in profitable systems of permanent agriculture, is due to the plant food it contains, and that the greatest problem in the handling of farm manure is to prevent the loss of plant food.

The value of average fresh farm manure is about $2.25 a ton, either when determined by chemical analysis on the basis of present market values for the plant food contained in the manure or when determined by the value of the increased crop yields produced when the manure is applied to the fields in ordinary crop rotations.

This means that a pile of average fresh farm manure containing 100 tons is worth $225. If exposed to leaching from heavy rains during only two or three months in the spring the value will be reduced, as a rule, from $225 to about $150 by the loss of plant food without much reduction in total weight. Indeed, the total weight is frequently increased under such conditions because the rain water that remains in the manure may be in greater amount than the urine that has been washed out. Fermentation and additional leaching during the summer may easily reduce the value to $100 or less. There are two satisfactory methods for handling manure. One of these is to haul and spread the fresh manure daily or at least two or three times a week. For this purpose a manure spreader, or, at least, a wagon used for this work only, is very useful and almost necessary. The other method is to allow the manure to accumulate in the stall or covered feeding shed while it is constantly tramped by the animals and kept moist by the liquid excrement, sufficient bedding being used to absorb the excess and to keep the stock clean, and then to haul and spread it on the land when conditions permit. It should not be left, however, to dry out and heat and decompose in the stalls or sheds long after the animals have been turned out to pasture.

Loss of Fertility by Selling Farm Produce

Every system of farming should be so planned as to be both profitable and permanent, which requires that the productive capacity

of the land must be maintained. We must understand, then, what the soil contains, what materials are required to produce crops, in which parts of the crops these different materials are deposited, so as to know what part of the produce may be sold and what part should be retained on the farm; also what is done with these important plant food materials when the crops are fed to live stock.

The older prairie and upland timber soils of the United States are, as a rule, exceedingly rich in potassium but relatively deficient in both nitrogen and phosphorus. In the worn hill lands nitrogen is usually more deficient than phosphorus, while in the average long-cultivated prairie soil phosphorus is more deficient than nitrogen.

When grain crops are produced, as corn, oats and wheat, about two-thirds of the nitrogen and three-fourths of the phosphorus, but only one-fourth of the potassium required for the crop are stored in the grain or seed, while about one-third of the nitrogen, one-fourth of the phosphorus and three-fourths of the potassium are stored in the straw or stalks.

Thus a large crop of corn, 100 bushels to the acre, will contain about 100 pounds of nitrogen in the grain and 48 pounds in the stalks, 17 pounds of phosphorus in the grain and 6 pounds in the stalks, 19 pounds of potassium in the grain and 52 pounds in the stalks. Quite similar relations exist between the grain and straw of other crops.

Now, with these facts in mind, it is plain to see that a system of farming by which the grain is sold and only the stalks and straw are kept on the farm and returned to the soil carries off in the grain much of the nitrogen and phosphorus. In both of these elements most soils are more or less deficient, while the potassium, of which the normal soil contains an almost inexhaustible supply, enough in the first 7 inches for 100 bushels of corn per acre every year for seventeen centuries, is largely returned in the straw and stalks.

It should be remembered that legume crops, as clover, alfalfa, cowpeas and soybeans, are rich in both nitrogen and phosphorus, 3½ tons of clover hay containing as much phosphorus and 40 pounds more nitrogen than 100 bushels of corn.

If the crops are fed to live stock, it is well to know that about one-fourth of the nitrogen and one-fourth of the phosphorus are retained in the flesh and bone of the animal, while three-fourths of the nitrogen and phosphorus and practically all of the potassium are

returned in the solid and liquid excrement. Thus we have another process of separation by which part of the needed nitrogen and phosphorus leaves the farm with the animals, while the potassium is again returned, even though it may not be needed.

It should be a plain fact that manure made from animal excrements with straw or stalks for bedding must be deficient in nitrogen and still more deficient in phosphorus, but rich in potassium, as compared with the requirements of the crop; and this is especially noteworthy when the manure is to be used on land already deficient in nitrogen and phosphorus but well supplied with potassium.

In the case of nitrogen the difficulty can be overcome by making a liberal use of clover or other legumes in the crop rotation and as catch crops, turning under these crops and crop residues so far as practicable. Legume crops may also be used in pastures to a considerable extent, thus securing nitrogen from the air to balance the deficiency in the manure. With the phosphorus the difficulty is greater, because the proportion contained in the manure is less and there is no such ever-present inexhaustible supply as in the case of nitrogen.

Increasing the Value of Farm Manure

It must be apparent that to increase the value of farm manure we should add phosphorus to it. Thus, we can balance manure, and when used on soils rich in potassium in rotations with nitrogen-fixing legume crops we can provide plant food in a balanced ration to meet the needs of the maximum crop yields. By these means we can check the progress of soil exhaustion and even gradually increase the fertility and productive capacity of the land. Indeed, we can thus profitably enrich such land even beyond its virgin fertility.

By far the cheapest form of phosphorus is fine-ground raw rock phosphate. This material is but slightly available for the use of crops if applied to soils deficient in decaying organic matter, but if applied in intimate connection with rotting manure it is thus made soluble and available for plant growth.

Certainly one of the most profitable, and probably the most profitable, method of maintaining the necessary supply of phosphorus in the soil is to put back into the manure in the form of fine-ground raw rock phosphate somewhat larger amounts of phosphorus than the animal has retained in his bones. It is well for a time at

least to put back larger amounts than the animals retain, because the soils are already deficient in phosphorus and also because there may be some waste of manure.

These statements are based both upon the chemical analysis of soils and crops and manures and also upon carefully conducted field experiments covering many years. Several experiment stations have furnished some valuable data from phosphate investigations, and a large amount of information is rapidly accumulating from our more extensive work in Illinois, but the most complete experiments of long duration are reported by the Ohio Experiment Station. Where 40 pounds of fine-ground rock phosphate, costing about 15 cents, were added to each ton of fresh manure and 8 tons of manure per acre were applied for a three-year rotation of corn, wheat and clover, the value of the increase in crop yields was equal to $3.49 for each ton of manure used, while the manure was worth only $2.33 per ton without the phosphate in case of fresh stall manure and only $1.72 per ton for open yard manure, these results being the average of 11 years' experiments on three different series of plots, based upon increased yields valued at 35 cents a bushel for corn, 70 cents for wheat, and $6 a ton for clover hay. If we deduct the cost of the phosphate used we still have what might be termed a net value of $3.34 a ton for the phosphated stall manure.

Of course it would be equally appropriate, and possibly more so, to speak of "manured phosphate" instead of "phosphated manure," because the rock phosphate actually furnishes the needed and deficient element, phosphorus, while the manure helps to make it available. On this basis we may say that the value of 40 pounds of rock phosphate is increased from 15 cents to $1.16 by mixing with a ton of stall manure, after deducting the value of the untreated manure.

The most important fact to keep in mind, however, is that both the manure and rock phosphate are much more valuable when used together than when used separately, because manure is deficient in phosphorus and rock phosphate does not act satisfactorily except in connection with rotting organic matter. As a rule, it is better to use sufficient rock phosphate with each ton of manure, so as to supply about 200 pounds of rock phosphate per acre for each year in the crop rotation.

It should be emphasized that the element phosphorus is the key to permanent agriculture on our great body of agricultural lands;

and the highest present duty of the people of the United States is to see to it that provision is made whereby our own phosphates, both high grade and low grade, may be applied to these soils, where they will remain until removed in the crops; and where, if the farm manures and all other recoverable residues are returned to the soil, they may be used for the production of crops over and over again.

Exportation of phosphate should cease, gradually if necessary, the exportation being limited to a million tons a year with an annual reduction of a hundred thousand tons, so that none would be exported after ten years. The Federal Government should undoubtedly control so far as necessary the mining and distribution of these phosphates with some limitations upon the profits that may be exacted by the phosphate owner from the agricultural people, in order that farmers and landowners may be encouraged to apply to their lands more phosphorus than is taken out in the crops removed.